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A REPORT ON THE PHOSPHATE FIELDS OF SOUTH CAROLINA.

By Wm. H. Waggaman,
Scientist in Investigation of Fertilizer Resources.

INTRODUCTION.

The first important discoveries of phosphorites or amorphous phosphates made in this country were those of South Carolina. For many years these fields furnished most of our supply and much of Europe's. But during the last 20 years the output has been gradually diminishing, owing in part to the exhaustion of the more readily accessible rock, but chiefly to the marketing of higher-grade phosphate from other sources.

Although many interesting and valuable articles and papers on these deposits have been published from the time of their first exploration in 1868 down to the year 1904, conditions in these fields have changed so materially during the last decade that it is thought advisable to issue the present bulletin. This reviews briefly the history of South Carolina phosphates, describes the present methods of mining and handling the rock, shows what disposal is being made of the product, and discusses the future of the industry.

HISTORY.

The existence of the phosphate stratum was known for many years before its true nature and value were recognized. As far back as 1839 [1] the upper portion of the heavy marl (including the phosphate stratum) was known as the "Fish Bed" of the Charleston Basin on account of the numerous teeth and bones of marine animals contained therein. In 1842 Edmund Ruffin [2] made an agricultural survey of South Carolina, but his report, which was issued the following year, dealt chiefly with the occurrence and extent of the marls of the State. Holmes [3] states that he and some of his associates submitted samples of the nodular phosphate to Ruffin for examination, but apparently

[1] Holmes, F. S. The Phosphate Rocks of South Carolina, p. 65 (1870).
[2] Chazal. A Sketch of the South Carolina Phosphate Industry, p. 34 (1904).
[3] The Phosphate Rocks of South Carolina, p. 57 (1870).

no determination other than that of their lime content was made. Holmes,[1] in 1844, described "a remarkable bed of nodules or conglomerates 12 inches thick bedded in clay which overlaid the heavy beds of marl."

Tuomey,[2] who succeeded Ruffin, issued a report in 1848 in which he described the same stratum and called the phosphate nodules "marl stones." He was convinced that they were derived from the underlying marl, for he says, "There is little more left than the silica and alumina of the marl." In the appendix of this same report [3] are a number of analyses made by Prof. Charles U. Shepard showing the phosphate content of the marl, but none showing the amount of phosphoric acid in the nodules. Holmes,[4] in a later publication, also regards the phosphate nodules as silicified fragments of the underlying marl.

Chazal[5] states that Prof. Charles U. Shepard was the first to point out the true value of the phosphate nodules. He quotes from a lecture delivered by Shepard before the medical society in 1859, which indicates that the latter was then acquainted with the nature of the phosphate stratum. Chazal also quotes from letters which show that Shepard had advised the use of the Ashley phosphates in lieu of bones as far back as 1860. The outbreak of the Civil War, however, put a stop to fertilizer operations, and it was not until 1867 that Dr. St. Julien Ravanel, Dr. F. S. Holmes, and Dr. N. A. Pratt revived interest in these deposits and obtained capital sufficient for their exploitation. To Dr. Pratt belongs the credit of the first recorded analysis of high-grade South Carolina phosphate.

From 1868, when 12,262 tons of rock were produced from the South Carolina fields, to the year 1893, which showed a production of 618,569 tons, the industry steadily grew, but since the latter date the production has diminished, till in 1911 the total amount mined was only 169,156 tons.

GEOGRAPHY AND TOPOGRAPHY.

The phosphate area of South Carolina lies along the coast in a belt, which is in places fully 20 miles wide, extending from the Wando River in Charleston County to the Broad River in Beaufort County. (See fig. 1.) The coast region as a whole is very little above tide level and is intersected with numerous creeks, rivers, and arms of the sea. Most of these streams are navigable and afford the phosphate operators a ready means of transportation for their product. Many of

[1] South Carolina Agriculturist (1844).
[2] Geology of South Carolina, p. 165 (1848).
[3] Geology of South Carolina. Appendix (1848).
[4] Post Pliocene Fossils of South Carolina. Introduction, p. II (1860).
[5] A Sketch of the South Carolina Phosphate Industry (1904).

the phosphate properties are reached by the Atlantic Coast Line, the Southern, and the Charleston & Western Carolina Railroads, or spurs from these roads.

CLASSES OF PHOSPHATE.

The South Carolina phosphate deposits are usually classified under two heads, namely, the "River Rock" and the "Land Rock."

The River Rock was at first the most easily exploited, since it was cleaner and after being dredged from the river bed required but little

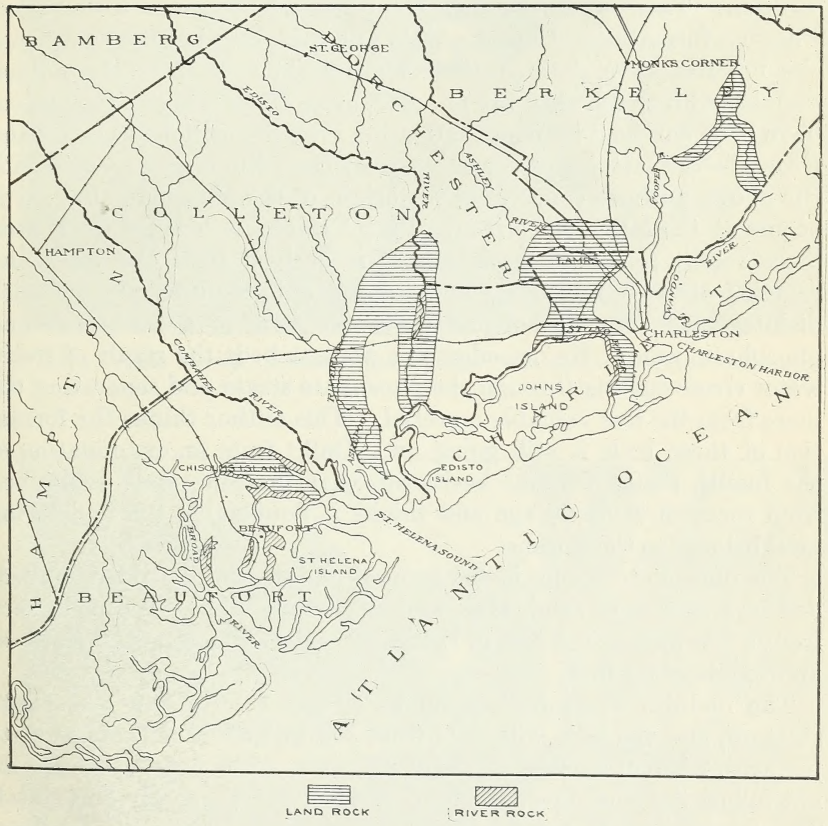

FIG. 1.—Approximate distribution of the South Carolina phosphates.

subsequent treatment to make it a marketable product. It was some time before a satisfactory method of mining and cleaning Land Rock was devised. The two types of phosphate, however, are practically identical, the River Rock being merely the Land Rock washed down and concentrated in the river beds.

The mining of River phosphate has now ceased and the rock shipped from South Carolina is all from the land and marsh deposits. This report, therefore, deals chiefly with the land deposits.

GEOLOGICAL OCCURRENCE AND ORIGIN.

The phosphate-bearing stratum belongs to the Tertiary period, but geologists differ considerably regarding the exact age of the phosphate.

Toumey[1] is of the opinion that the phosphate nodules are derived from the fragments of the Eocene marl on which the beds rest. This author, however, was unacquainted with the true nature of the phosphate. Holmes,[2] Shepard,[3] and Chazal[4] also think the nodules are waterworn fragments of the Eocene marl enriched by the leaching out of the carbonate of lime and absorption of phosphoric acid from solution. These authors assign the phosphate stratum to the post-Pliocene formation. Chazal points out that it is hardly likely that the nodules have derived their phosphoric acid from the animal remains with which they are mingled, since these remains themselves have been enriched by phosphatization after deposition. Levat[5] and Brown[6]—the latter quoting extensively from the former—agree with the above authors concerning the origin of the phosphate, but say it occurs at the Miocene horizon. Pratt[7] thinks it belongs to an even more recent formation and that it is derived from the feces and remains of both terrestrial and marine animals intermingled with disintegrated coral and deposited in the form of a calcareous and phosphatic mud. He considers the present beds the result of fresh-water rivers cutting through the phosphate strata and separating the more from the less valuable material. This author thinks the formation of these beds is still going on. Dall,[8] from an examination of the fossils, states without hesitation that the phosphate is derived from rocks of Miocene age and thinks it doubtful if the underlying marl belongs to the Eocene.

The phosphate occurs in the form of nodules and bowlders embedded in a matrix of sand, clay, and calcareous mud. The beds vary from a few inches to 3 feet in thickness, with an average thickness of approximately 1 foot.

The nodules average from 30 to 50 per cent of the phosphate stratum, and the beds will yield from 300 to 1,500 tons of phosphate per acre, with an average of about 850 tons. The beds, as a rule, do not follow the coutour of the land surface, but lie nearly horizontal. The overburden, therefore, varies considerably from place to place.

Although only the upper stratum is mined, phosphate nodules are found at more than one horizon. The following table of Prof.

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[1] Geology of South Carolina, pp. 164, 165 (1848).
[2] Phosphate Rocks of South Carolina, pp. 27–31 (1870).
[3] South Carolina Phosphates, pp. 22–24 (1880).
[4] A Sketch of the South Carolina Phosphate Industry (1904).
[5] Industrie des Phosphates et Superphosphates, pp. 83–84.
[6] Eng. Assoc. of the South Trans. 15, pp. 58–60 (1904).
[7] Native Bone Phosphates of South Carolina, pp. 24–28 (1868).
[8] Amer. Jour. Sci., ser. 3, p. 296 (1894).

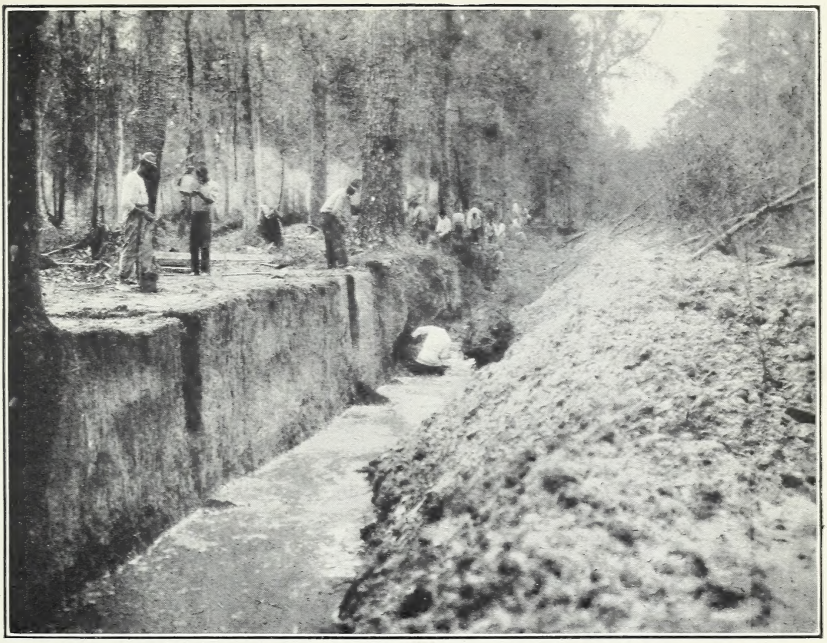

FIG. 1.—HAND MINING. REMOVING OVERBURDEN FROM SOUTH CAROLINA PHOSPHATE.

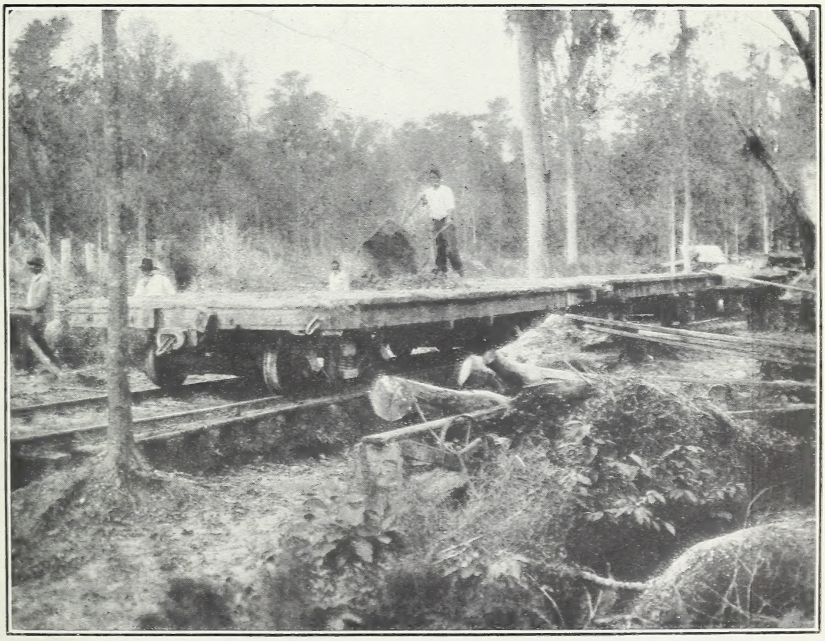

FIG. 2.—LOADING PHOSPHATE ON FLAT CARS BY HAND.

Shepard, published by Chazal,[1] shows the various strata and their content of phosphoric acid.

TABLE I.—*Thickness and character of strata in phosphate regions of South Carolina as determined from a well.*

Character of stratum.	Depth of strata.	Content of phosphoric acid.	Equivalent in bone phosphate of lime.
	Feet.	*Per cent.*	*Per cent.*
Clay	17- 20	0.42	0.92
Phosphatic nodules	26- 30	26.79	58.48
Marl	26- 30	3.07	6.70
Do	34	3.01	6.57
Argillaceous marl	46	2.03	4.43
Phosphatic nodules	70	22.72	49.59
Argillaceous marl	85	1.26	2.74
Do	90	1.51	3.30
Phosphatic nodules	104	13.38	29.20
Do	110–112	23.60	51.52
Argillaceous marl [1]	110–112	10.65	23.24
Phosphatic nodules	125–128	15.81	34.91
Hard marl	125–128	1.23	2.68
Argillaceous marl	145	Traces.	.....
Do	170	Traces.	.....
Do	228	Traces.	.....
Do	255	Traces.	.....
Phosphatic nodules	280	22.47	49.05
Argillaceous marl	286	.60	1.31
Marl and phosphatic grains	287–290	5.96	13.01
Argillaceous marl	300–305	3.37	7.37
Sandy marl	305–306	.90	1.96
Do	307	.80	1.75
Hard marl	309–311	.63	1.37
Phosphatic pebbles	312–313	27.72	60.52
Hard pebbly marl	312–313	2.47	5.39
Sandy limestone	315–316	1.02	2.22
Firm limestone	321–322	.95	2.07
Sandy limestone	323	1.05	2.29

[1] Including phosphatic nodules.

PHYSICAL AND CHEMICAL PROPERTIES.

The South Carolina phosphates occur in nodules varying from the size of sand grains to bowlders weighing several tons. The rock varies in hardness and texture from soft porous material to hard, lustrous, flintlike pieces. The nodules are sometimes smooth rounded or kidney shaped, closely resembling "coprolites," but more often they are irregular in shape, pitted, or completely perforated, the holes usually being filled with sand and clay, which has to be removed by washing. In color the rock varies from grayish white to almost jet black, and between these two extremes there are a variety of shades of red, yellow, and brown.

The River Rock and that found in the marshes is usually darker in color than that found farther inland, owing probably to a larger percentage of organic matter. The rock varies in specific gravity from 2 to 2.5; and from a large number of determinations made by Shepard the average is 2.4. The nodules are usually denser and harder on their surface than in the interior, but this is not always so.

[1] Sketch of the South Carolina Phosphate Industry, p. 26 (1904).

After calcining, the rock becomes more brittle and can be readily and cheaply ground.

Although the South Carolina phosphate is considerably lower in grade than that from many other sources, it makes an acid phosphate of excellent quality and good mechanical condition for mixing purposes. Some farmers prefer this material to the higher grade product made from Florida or Tennessee phosphate.

The rock now marketed contains on the average about 61 per cent of bone phosphate of lime, though individual nodules and fragments are sometimes found which contain as much as 75 per cent. The following table, compiled by Chazal from analyses made by Shepard, gives the composition of South Carolina phosphate from different localities. The samples from which these analyses were made were collected during the early development of the South Carolina phosphate industry and are of somewhat lower grade than the rock which is now obtained from some of the same localities.

TABLE II.—*Phosphate content of South Carolina phosphate rock from various sources.*

Location.	Description.	Moisture.	P_2O_5, undried basis.	$Ca_3(PO_4)_2$, undried basis.	$Ca_3(PO_4)_2$, dried basis.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Stone River	Light colored	3.68	25.61	55.91	58.04
Do	Dark colored	.....	20.68	58.24	.....
Do	Large bowlder	1.50	25.70	56.21	57.07
Ashley River, land deposit	Hot air-dried cargo sample	.00	27.01	58.95	58.95
Cooper River, land deposit	.....	10.07	27.11	59.18	.....
Chisolms Island	Hot air-dried cargo sample	.84	27.26	59.51	60.00
Bull River	.....do	.79	25.14	54.88	55.32
Coosaw River	.....do	.57	27.26	59.51	59.85
Do	.....do	.66	26.78	58.46	58.85

METHODS OF MINING.

For many years the mining of South Carolina phosphate was carried on by hand labor. For a short time even the washing of the phosphate was done by hand. The product, therefore, was at first regarded rather unfavorably, as it was not clean and produced an acid phosphate of poor quality. The early methods of mining and handling the rock have been largely supplanted by modern and more efficient methods, which turn out a clean, dry product well fitted for the manufacture of acid phosphate. Hand mining is still economically practiced where the overburden is sufficiently light and of such a character as to render the steam shovel unnecessary, but washing by hand has been entirely supplanted by the modern washer plant capable of turning out from 150 to 600 tons of clean rock every day. Hand mining (see Pl. I, figs. 1 and 2) is carried out as follows:

After thorough prospecting to determine the extent and value of the phosphate property, a ditch is dug through or alongside the tract to be mined and below the level of the phosphate stratum. Laterals

drain into this ditch from the phosphate trenches, which are thus kept comparatively dry. A main line of railroad is established, and spurs from this are run out to the phosphate trenches in such a way that the material can be loaded easily into flat cars and hauled cheaply to the washer plant.

Hand mining is usually performed on contract, a certain price being paid for the rock delivered at the washer. The contractor in turn pays the laborers by the task, assigning each man a section of the phosphate property, from which he removes the overburden and digs out the phosphate and loads it on the cars. Where the overburden is 8 feet or more in thickness steam shovels are employed to remove it. This machine digs a canal about 20 feet wide, depositing the overburden on one bank, while a hoist equipped with a single grab bucket, or a series of buckets to be loaded by hand, runs on a track on the opposite bank of the canal. As fast as the steam shovel removes the overburden from the deposit the hoist is used to place the phosphate thus exposed on the cars. When the limit of the deposit is reached the steam shovel returns, dredging out a canal adjacent to that already dug and depositing the overburden in the old ditch. Many deposits which could not be economically worked by hand are now rendered valuable by the advent of machine mining. (Pl. II, figs. 1 and 2.)

WASHING THE ROCK.

After the washing of the material by hand had been abandoned as entirely inadequate and inefficient, log washers similar to those now used in Florida[1] were introduced. The matrix in which the South Carolina phosphate is embedded, however, is of such a loose character that an elaborate cleansing process is unnecessary, so that log washers have been supplanted. By the present method the rock is scraped into a hopper, which discharges into a mechanical conveyor composed of units holding one-half ton each. It is carried to the top of the washer, where each unit of the conveyor is automatically discharged, and a stream of water washes its contents down to a crusher. From the crusher it is discharged through troughs into the lower end of several cylinder washers, which vary in number from two to eight, depending upon the size of the plant. Each cylinder is 27 feet long and 5 feet in diameter, the discharge end being 14 inches higher than the end where the phosphate material enters. The first part of the lower end and the last 2 feet of the upper end are composed of heavy wire screen, having perforations of a dimension three-sixteenths by three-fourths inch.

The interior of the cylinders is fitted with plates arranged in the form of a spiral so that they throw the phosphate forward and toward

[1] Waggaman, Bul. No. 76, Bureau of Soils, U. S. Dept. Agr. (1910).

the upper end as the cylinder revolves. A 2-inch stream of water under a pressure of 60 pounds to the square inch is played upon the phosphate material from the upper end of the cylinder. This washes the sand, clay, and finely divided phosphate down to the lower end of the cylinder where it escapes through the screen and then flows out through a trough to the wash heap, which is usually located at some distance from the plant. The washed rock falls from the upper end of the cylinder upon a rubber-coated belt 26 to 30 inches in width, along which it is carried to the wet bins. Pickers are stationed along this belt for the purpose of removing clay balls, marl, and any other foreign material which may be mixed with the phosphate. From the wet bins the rock is drawn into cars and sent to the drying sheds, where it is burned on ricks of wood. About 6 cords of wood are required to dry 100 tons of phosphate from a moisture content of 15 per cent down to a moisture content of 0.5 per cent.

COST OF PRODUCTION.

Unfortunately for the South Carolina phosphate industry, the cost of production has increased without a corresponding advance in the price of phosphate rock. Indeed, the price of this material is now so low that the smaller operators in these fields have entirely ceased mining.

The increased cost of mining is largely due to the practical exhaustion of the more accessible deposits. It is now frequently necessary to remove an overburden of 15 to 20 feet in order to uncover the phosphate stratum, where formerly there were hundreds of acres of rock lying practically at the surface or covered by only a foot or two of soil.

The price of labor has also advanced from 30 to 50 per cent, and frequently it is so difficult to obtain hands that the output of rock is seriously curtailed. The equipment of a modern phosphate plant is both elaborate and costly. Steam shovels for excavation, grab buckets and hoists for taking out the rock, many miles of steel rails, locomotives and flat cars for haulage purposes, heavy machinery for washing the rock, and large sheds for drying and storing the product are essential parts of the present mining system. (Pl. III, figs. 1 and 2.)

On account of the topography of the South Carolina coast, weather and tide conditions affect the output of phosphate rock. In rainy weather or when the tide is very high the trenches are continually filling with water, the banks caving in, and the continual use of pumps is necessary to make mining possible. The output of rock under such conditions is often cut in half, thus practically doubling the cost of mining per ton.

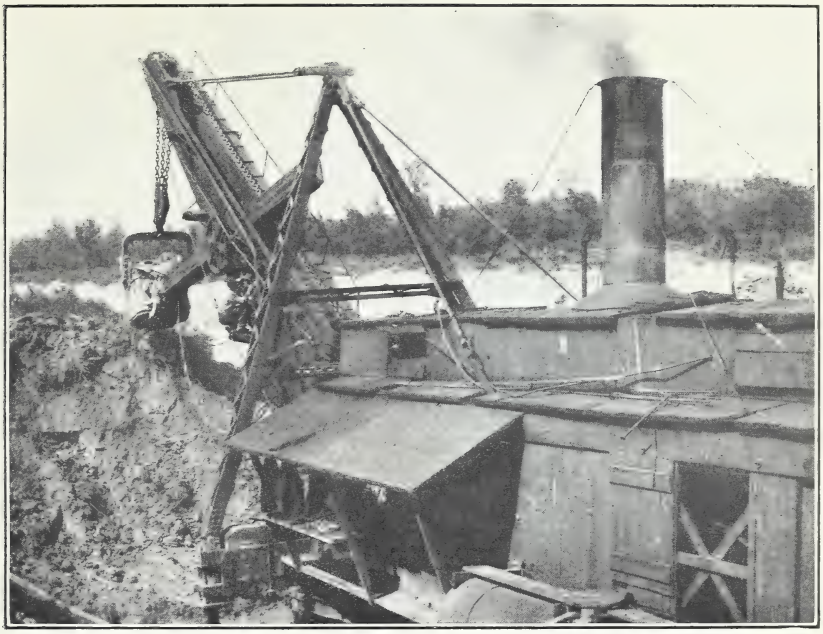

FIG. 1.—MACHINE MINING. REMOVING OVERBURDEN WITH STEAM SHOVEL.

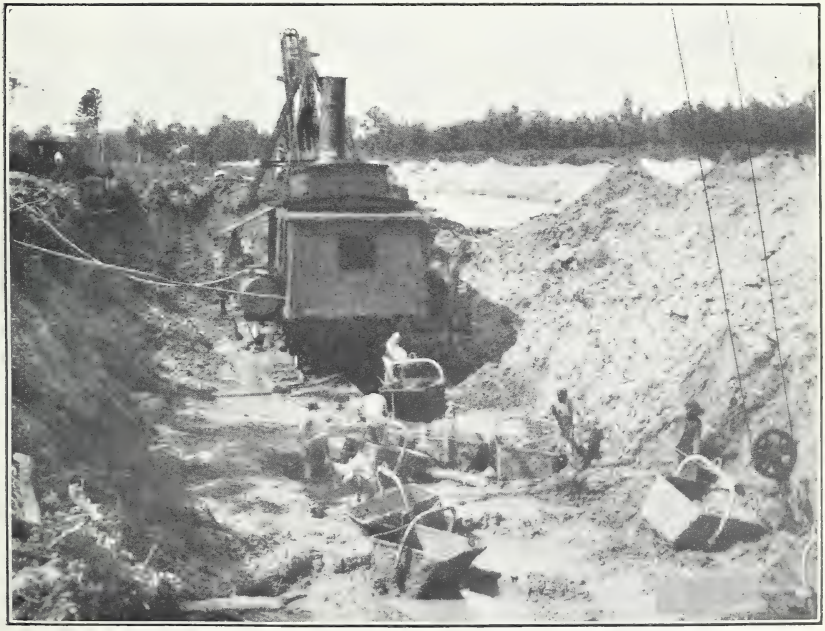

FIG. 2.—LOADING UNWASHED PHOSPHATE INTO BUCKETS TO BE HOISTED ONTO FLAT CARS.

FIG. 1.—LOAD OF PHOSPHATE READY FOR THE WASHER.

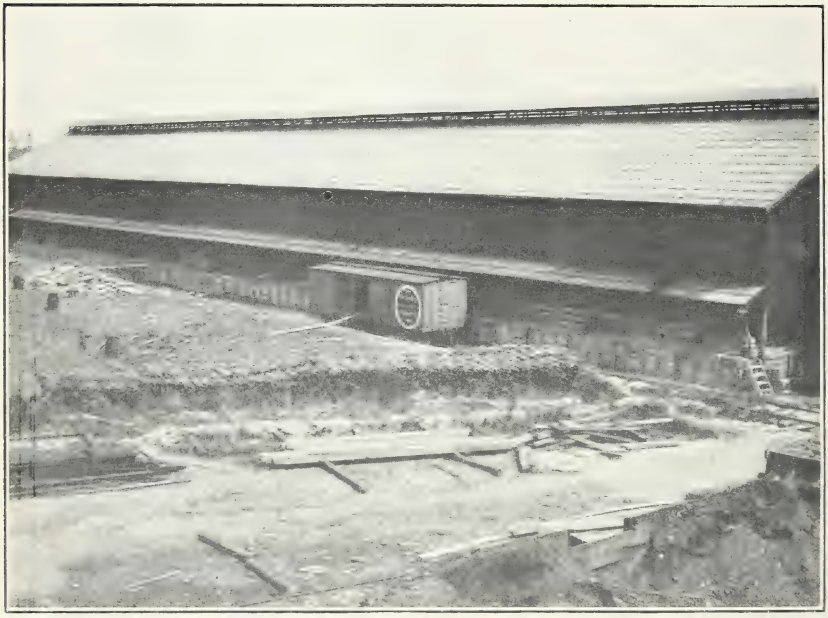

FIG. 2.—DRYING AND STORAGE SHED FOR PHOSPHATE ROCK.

These numerous and widely varying factors make it very difficult to strike an average for the cost of producing high-grade South Carolina phosphate, but the following figures, compiled from data obtained in these fields and from the author's own observation, are probably as close approximations as can be obtained.

TABLE III.—*Average cost per ton of producing South Carolina phosphate.*

Item.	Expense.	Item.	Expense.
Labor in mining	$1.50	Insurance	$0.05
Labor on washer	.10	Taxes	.05
Labor on dryer	.05	Overhead charges	.10
Haulage	.30	Depreciation	.75
Fuel for power plant	.04		
Fuel for drying rock	.12	Total	3.46
Interest on investment	.40		

WASTE MATERIAL.

In mining and preparing South Carolina rock for the market the same sources of waste are encountered as in the production of Florida phosphate. The loss of finely divided phosphate (held in suspension and passing through the cylinder screens) incident to the present method of cleaning the rock is very great, though not as great proportionally as the loss in washing the Florida product.[1] The phosphate stratum will yield on an average about 40 per cent phosphate rock; the remaining 60 per cent, consisting of sand, clay, and finely divided phosphate, is discharged upon the waste heaps. An analysis of material from the dumps made by the Bureau of Soils showed a content of about 13 per cent bone phosphate of lime, which means that over 20 per cent of the phosphate taken from the mines is discarded. Another, though minor, source of waste is at the picking board or belt where the clay balls, marl, etc., are removed by hand Inexperienced and careless pickers frequently throw away much good material.

DISPOSAL OF PRODUCT.

Although some specimens of South Carolina rock contain as high as 75 per cent of bone phosphate of lime, the average grade of the marketed product is about 61 per cent. Almost the entire output is sold in the State on a guaranty of 60 per cent of bone phosphate and made into acid phosphate by the local factories. The present price of South Carolina rock f. o. b. at the mines is about $4 per ton.

Some rock is shipped to neighboring States and a small amount as far north as Richmond, Va., but the freight rates will hardly admit of its shipment any great distance. The price of the higher grade Tennessee and Florida phosphate f. o. b. at the mines is so

[1] Waggaman, Bul. No. 76, Bureau of Soils, U. S. Dept. Agr. (1911).

much lower that they can be delivered in Charleston, S. C., at a price but little above that of the local product. Finely ground South Carolina phosphate has been tried a number of times on the soils of South Carolina and Georgia. But little success has been reported, although the increasing use of this form of phosphatic fertilizer in the Middle West indicates the desirability of further investigation.

EXTENT OF OPERATIONS.

The South Carolina phosphates (Land and River Rock) have been extensively mined in a number of localities—on both sides of the Ashley River, on the banks of the Stono River and in the stream itself, south of the Ashepoo River on Chisolms and Willimans Islands, and in the Coosaw and Beaufort Rivers.

The most productive area of Land Rock has been what is known as the Ashley River Beds, which lie on both sides of the Ashley River, extending more or less uniformly over an area of about 200 square miles. Most of the River Rock marketed in past years was dredged from the Coosaw River, but mining operations there have been discontinued, owing to the depletion of the richer beds of phosphate and to the inability of the mining company to pay the royalty required by the State.

PRESENT CONDITION OF THE INDUSTRY.

The present condition of the phosphate industry in South Carolina is not good. The increased cost of mining, together with the low price of the product, has forced the small operator either to abandon his plant or to sell to the larger companies.

There are at present only two concerns engaged in mining South Carolina phosphate, and these are operating a total of four washer plants. The largest of these washers is at Lambs, on the Ashley River. Two smaller ones are located on the Stono River, about 9 miles west of Charleston, and the fourth is at Chisolms Island, Beaufort County. The total output of rock in 1911 was, according to the United States Geological Survey, 169,156 tons.

FUTURE OF THE INDUSTRY.

Those interested in phosphate mining are rather discouraged at the outlook in South Carolina.

There is little indication of any immediate rise in the price of rock, and the cost of preparing the phosphate for the market leaves such a narrow margin of profit that mining is only made commercially practicable by the use of up-to-date machinery capable of handling large quantities of material. Adverse weather or labor conditions decrease the margin of profit.

Contrary to general opinion, however, the South Carolina fields are far from exhausted. Thousands of acres of good phosphate land still remain unmined, and though the overburden on much of this property is rather heavy, improvements in mining methods will some day render it all available for fertilizer purposes.

An estimate of the actual quantity of phosphate still remaining in South Carolina is necessarily rough, for, though some of the lands have been thoroughly prospected, large areas have not been touched. Chazal,[1] in 1904, estimated the quantity of South Carolina phosphate still available at from 9,000,000 to 11,000,000 tons. Since that time less than 2,000,000 tons of rock have been marketed, which would leave between 7,000,000 and 9,000,000 tons. Chazal's estimate seems quite conservative, and the author is inclined to place the available tonnage somewhat higher. Suffice it to say, however, that these South Carolina fields can continue to produce rock at the present rate for many years to come.

SUMMARY.

The South Carolina phosphates were the first important deposits discovered in this country. They have been worked since 1868, and for many years produced most of our supply of phosphatic fertilizer.

The phosphate region lies along the coast in a belt extending from the Wando River, in Charleston County, to the Broad River, in Beaufort County. The rock is of Tertiary age and is usually divided into two classes, namely, the land deposits and the river deposits. These classes, however, are practically identical, the latter being merely the former washed into the river beds.

The rock is mined by first removing the overburden, either by hand or by steam shovels, and then digging out the phosphate stratum thus exposed. The rock is embedded in a matrix of sand and clay, which is removed by a washing process. During this washing much phosphate is discharged and lost in the detritus. The washed rock is afterwards dried by burning on ricks of wood.

With the exhaustion of the more accessible deposits and the discovery of higher grade phosphates in Florida and Tennessee, the output from South Carolina has fallen off considerably. River mining has entirely ceased, and only two companies are mining the Land Rock. The total output in 1911 was 169,156 tons.

The average cost of producing South Carolina phosphate for the market is about $3.46 per ton. This is so little below the present selling price of rock that the rock can not be profitably shipped. Most of it is therefore used locally in the manufacture of acid phosphate.

[1] Sketch of the South Carolina Phosphate Industry, p. 18 (1904).

The general opinion has been that the phosphates of South Carolina are practically exhausted. This is far from being the case. There are thousands of acres of rich phosphate land still practically untouched. Although the phosphate on much of this property is covered by a heavy overburden, more efficient mining methods and improved market and transportation conditions would render it all available.

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